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Art. XII.—*The Relationship between Dacite and Granodiorite in Victoria.*

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(With one text figure.)

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The association and field relations of dacite and granodiorite[1] at Macedon, Mt. Dandenong, Warburton and Healesville, together with the somewhat related occurrences in the Cerberean Ranges, the Strathbogie Ranges, and the Tolmie Highlands, furnish interesting material for students in petrogenesis, and in the mechanics of igneous intrusion.

In all cases the evidence proves that there was an extrusion of lava, followed by the intrusion of granodiorite or adamellite in such a manner that in every area the plutonic and volcanic rocks are brought into contact with one another. As a result of this relationship the dacite, etc., show the effects of contact metamorphism.

The Macedon occurrence is the best known, and may be taken as more or less typical of the relations that exist in the areas named.

The general field relations of the rocks in this area are shown in the map and section (fig. 1). It will be seen that the dacite is shown resting on the granodiorite over a considerable area. As the dacite has been proved to be the older rock, it follows that it must have been piled up on a platform of Ordovician sediments, and that the present justaposition of the dacite and granodiorite has been brought about subsequently.

The relationship of the batholith of granodiorite to the overlying dacite does not seem explainable by Suess's[2] conception that a batholith occupies a space formed during the dislocation of the lithosphere.

Iddings'[3] modification of this idea, viz., "that as the lithosphere in places tended to part, molten magma might enter the fracture and because of its density and hydrostatic pressure might permit the fractured parts to separate, the magma supporting its share of the overlying load," also finds little support in the occurrence under discussion. Iddings considers that the tendency to part is the result of fracturing by thrusting and flexure. It is difficult to picture any

1. Richards, H.C., Proc. Roy. Soc. Vic., Vol. 21 (n.s.), p. 528, 1908.
Skeats, E. W., Q.J.G.S., Vol. 66, p. 450, 1910.
Skeats, E. W., and Summers, H. S., Geol. Surv. of Vic., Bull. 24, 1912.
Summers, H. S., Proc. Roy. Soc. Vic., Vol. 26, (n.s.), p. 256, 1914.
Morris, M., Proc. Roy. Soc, Vic., Vol. 26 (n.s.), p. 331, 1914.
Junner, N. R., Proc. Roy. Soc. Vic., Vol. 27, (n.s.), p. 261, 1915.
2. Suess. E., The Face of the Earth, Vol. 1, page 163, 1904.
3. Iddings, J. P., The Problem of Volcanism, p. 197, 1914.

such fracturing occurring between a dome-shaped mass of volcanic rock, and the platform on which it rests.

Turning to the hypothesis of overhead or magmatic stoping[4] it is found that this hypothesis is capable of giving a reasonable explanation of the occurrences under discussion.

The original magma before the extrusion of the volcanic phase, by means of overhead stoping reached sufficiently near the surface for partial collapse of the batholithic roof to take place, or alternately for the production of fissures connecting the batholithic chamber with the surface. In either case escape to the surface of the upper portion of the magma could take place.

In the Macedon area there is no evidence of the occurrence of any pyroclastic material so that the extrusion was not accompanied by any explosive action. The lava must have been fairly viscous, as the dacite was piled up in a dome-shaped mass, and wide spread lava flows are not found. A small flow occurs forming a tongue to the south west of Upper Macedon. At Healesville, and near Lilydale, in the Mt. Dandenong area, pyroclastic material has been recorded, indicating that conditions were somewhat different in those areas. Dome-shaped masses of dacite are also found in the Dandenong and Healesville areas.

Solidification of the dacite sealed up the vents from the batholithic chamber, and conditions became favourable for the resumption of stoping, with the result that the palaeozoic platform was entirely removed from a considerable area, bringing the granodiorite in direct contact with the dacite. If this explanation be correct then we might expect to find in some area portion of the old platform which had not been entirely removed, and which should occur between the dacite and granodiorite. So far no such occurrence has been recorded, but may exist, and further field work along the contacts should be done.

The dacites and granodiorites are closely related chemically, but exhibit distinct mineralogical differences. Near Braemar House (now called Clyde) in the Macedon district, both these rocks occur, and analyses are given in the following table. A complete list of the analyses is not necessary as all have been recorded, together with variation diagrams, in the publications quoted on the first page of this paper.

The typical dacite of Macedon consist of phenocrysts of labradorite and hypersthene with smaller and less numerous phenocrysts of ilmenite and biotite set in a granulitic groundmass, consisting of quartz, orthoclase, plagioclase, biotite and ilmenite.

The phenocrysts of labradorite and hypersthene generally show corrosion, but this is more marked in the pyroxene than in the felspar. Biotite frequently occurs in aggregates bordering the hypersthene. The granodiorites consist of quartz, labradorite, orthoclase, and biotite, the ratio of plagioclase to orthoclase being nearly 6 to 1. The prin-

4. Daly, R. A., Am. Jour. of Sc., Vol. 15, p. 269, 1903.
Igneous Rocks and their origin, 1914.

cipal mineralogical difference is the presence of the hypersthene in the dacite, and its absence in the granodiorite.

In most cases the groundmass of the dacites is holocrystalline, but in two places, viz., at Cheniston, near Upper Macedon, and at Hesket,

	I.	II.
SiO_2	62·54	64·04
Al_2O_3	16·66	15·58
Fe_2O_3	1·04	0·80
FeO	5·54	4·47
MgO	2·68	2·64
CaO	3·92	3·52
Na_2O	2·66	2·42
K_2O	2·47	2·80
H_2O+	0·46	2·25
H_2O-	0·17	0·38
CO_2	nil	nil
TiO_2	1·20	0·80
P_2O_5	0·20	0·18
MnO	tr.	tr.
Li_2O	tr.	tr.
Cl.	tr.	tr.
	99·54	99·88

I. Dacite 50 yards south of Braemar House (Clyde) Stables.
II. Granodiorite, near Braemar House (Clyde).

are types with fine grained groundmass, consisting of devitrified glass. These types occur near the outer margin of the base of the dacite dome, and are practically in contact with the Ordovician sediments, and so may be taken to represent portion of the original chilled margin. Sections of these two rocks show the presence of the ordinary phenocrysts, so that it seems certain that the phenocrysts had developed prior to extrusion. With the exception of biotite, the phenocrysts are of the high temperature dry fusion type. In the normal dacite the biotite occurs most commonly as aggregates bordering the hypersthene crystals. Near the contact between the dacite and granodiorite the first sign of contact metamorphism is the production of more mica at the expense of the hypersthene, until near the junction of the two rocks the hypersthene is seen to be completely replaced by a mixture of biotite and quartz. The biotite has been formed by reaction between hypersthene and the alkali felspar molecules in the groundmass.

The Hesket and Cheniston types are practically free from biotite so that it may be inferred that the temperature of the magma at the time of extrusion was rather higher than the reaction temperature between hypersthene and alkali felspar, but that in part the cooling after extrusion was sufficiently slow for some reaction to take place.

In the Strathbogie Ranges, and the Tolmie Highlands, the effusive type is better described as quartz porphyrite, being rather more acid and distinctly coarser in grain than the typical dacite. The groundmass has the same granulitic texture, and the phenocrysts are labradorite and biotite with rather rare examples of corroded hypersthene. This suggests that differentiation had proceeded rather further, and that the temperature at which crystallisation ceased had been sufficiently low for the reaction between the hypersthene and felspar to be almost complete.

Dr. N. L. Bowen's[5] theory of differentiation by sinking of crystals provides the most reasonable explanation of the relationship of the dacites to the granodiorites.

It has been shown that in the Macedon area, at the time of the extrusion of the dacite, labradorite and hypersthene had crystallised out, and that the still molten material containing alkali felspar molecules was commencing to react with the hypersthene to form biotite. The magma at this time would contain a certain proportion of water and other volatile ingredients, and some of these gases would escape when the lava reached the surface. This loss of water, etc., and the expansion of the lava due to loss of pressure, would serve to convert a magma sufficiently fluid to be able to slope its way upwards into a moderately viscous lava, incapable of extensive flow from the vent. Solidification at the border under these conditions would be rapid, and no further reaction between the hypersthene and felspar molecules would take place. Away from the margin a higher proportion of biotite would be formed, owing to slower cooling, and the lower temperature of final consolidation due to less loss of volatile constituents.

The solidification of the lava would seal up the batholithic chamber, and crystallisation of the remaining magma would continue at gradually decreasing temperatures.

Bowen believes that differentiation is mainly due to the sinking of crystals, so that the magma shows increasing acidity upwards. In the cases under consideration the upper, more acid portion, found its way to the surface, and the upper portion of the material left in the magma reservoir would be less acid than that which had reached the surface. Further crystallisation and sinking of crystals could go on, and this new upper layer would constantly gain in acidity. According to the length of time between the extrusion and the final solidification of the magma in the reservoir, so would the relative silica percentage of the volcanic and plutonic phases vary.

At Macedon the plutonic rock is the more acid, so that the assumption is made that there was a considerable period, relatively between the extrusion of the dacite and the final solidification of the granodiorite.

At the Strathbogie Range only two analyses have been made, one of quartz porphyrite from near Violet Town, and the other of the plutonic type from near Trawool. The plutonic type has the lower silica percentage. The temperature of the volcanic phase at Strathbogie, at the time of extrusion, was lower than that of the Macedon dacite, and differentiation was further advanced. This is shown by the almost complete replacement of hypersthene by biotite, and the greater acidity of the Strathbogie rock.

5. Bowen, W. L., Jour. of Geology, Vol. 23, No. 8, Supplement, 1915, and later papers.

After the extrusion the remaining magma would continue crystallising, but with a lower initial temperature than was the case in the Macedon area. Complete solidification would take place in a shorter period (other conditions being equal), so that the sinking of crystals ceased while the silica percentage of the plutonic type was below that of the extended rock.

The Mount Dandenong and Healesville areas are more complex as toscanites and rhyolites are associated with the normal dacites. No reliable analyses of the plutonic types in these areas have been published. Mr. M. Morris has been working out the relations in these areas, but has so far not published the results of his work, so that they cannot be discussed at present.